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Hunsaker

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(54) **PHYSICAL WRITE PACKETS PROCESSING WHEN POSTED WRITE ERROR QUEUE IS FULL, WITH POSTED WRITE ERROR QUEUE STORING PHYSICAL WRITE REQUESTS WHEN POSTED WRITE PACKET FAILS**

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(51) **Int. Cl.**⁷ **G06F 13/00**; G06F 13/38; G06F 11/00; G06F 11/16; G06F 3/06

(52) **U.S. Cl.** **710/52**; 710/29; 710/38; 710/39; 710/53; 710/57; 710/112; 714/48

(58) **Field of Search** 710/22, 29, 30, 710/38, 39, 52, 53-57, 112; 709/212, 236, 238; 714/48, 49, 54, 798, 799

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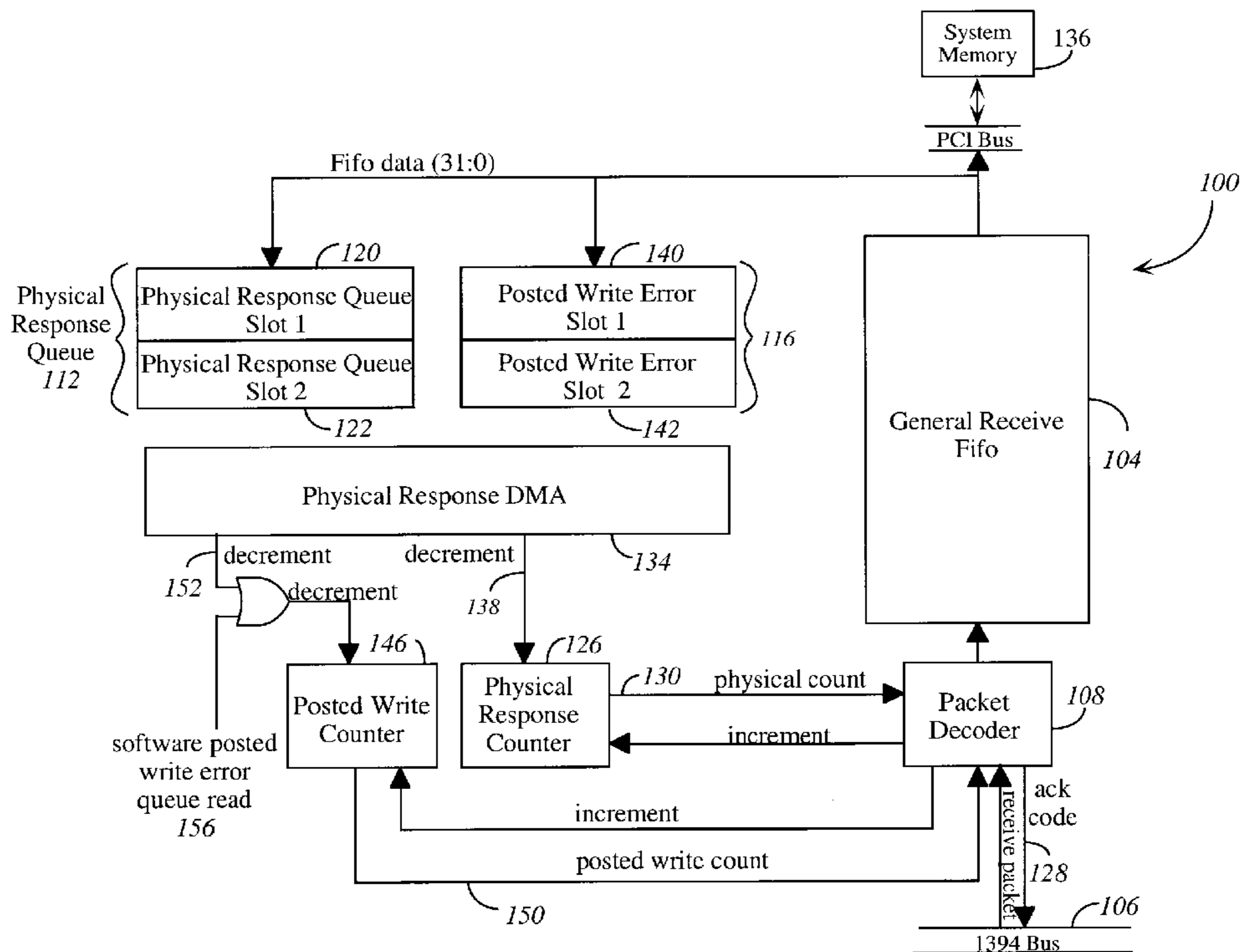
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(57) **ABSTRACT**

A system for handling write requests is described. The system uses two queues for storing posted write requests. When a posted write error results, software handles the posted write error using information stored in a first queue of the two queues. The write request producing the posted write error is cleared from the second queue which continues to handle physical packets containing write requests.

16 Claims, 4 Drawing Sheets



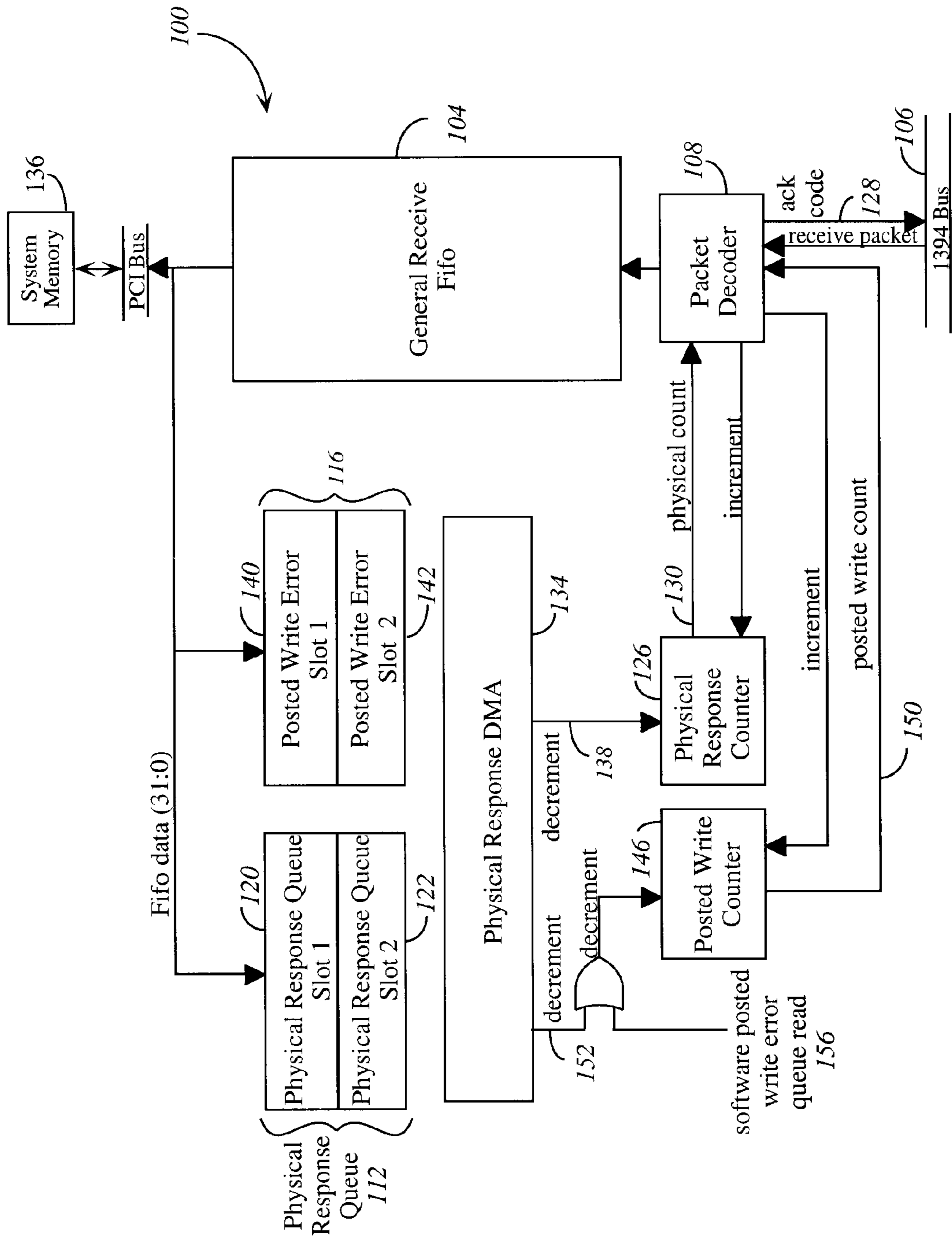


Figure 1

| Physical Packet Type | Physical Response Queue | Posted Write Error Queue | Ack Code |
|----------------------|-------------------------|--------------------------|--------------|
| Write Request | Not Full (count < 2) | Not Full (count < 2) | ACK_COMPLETE |
| Write Request | Not Full (count < 2) | Full (count = 2) | ACK_PENDING |
| Write Request | Full (count = 2) | Does not care | ACK_BUSY |
| Read or Lock Request | Not Full (count < 2) | Does not care | ACK_PENDING |
| Read or Lock Request | Full (count = 2) | Does not care | ACK_BUSY |

Figure 2

Figure 3A

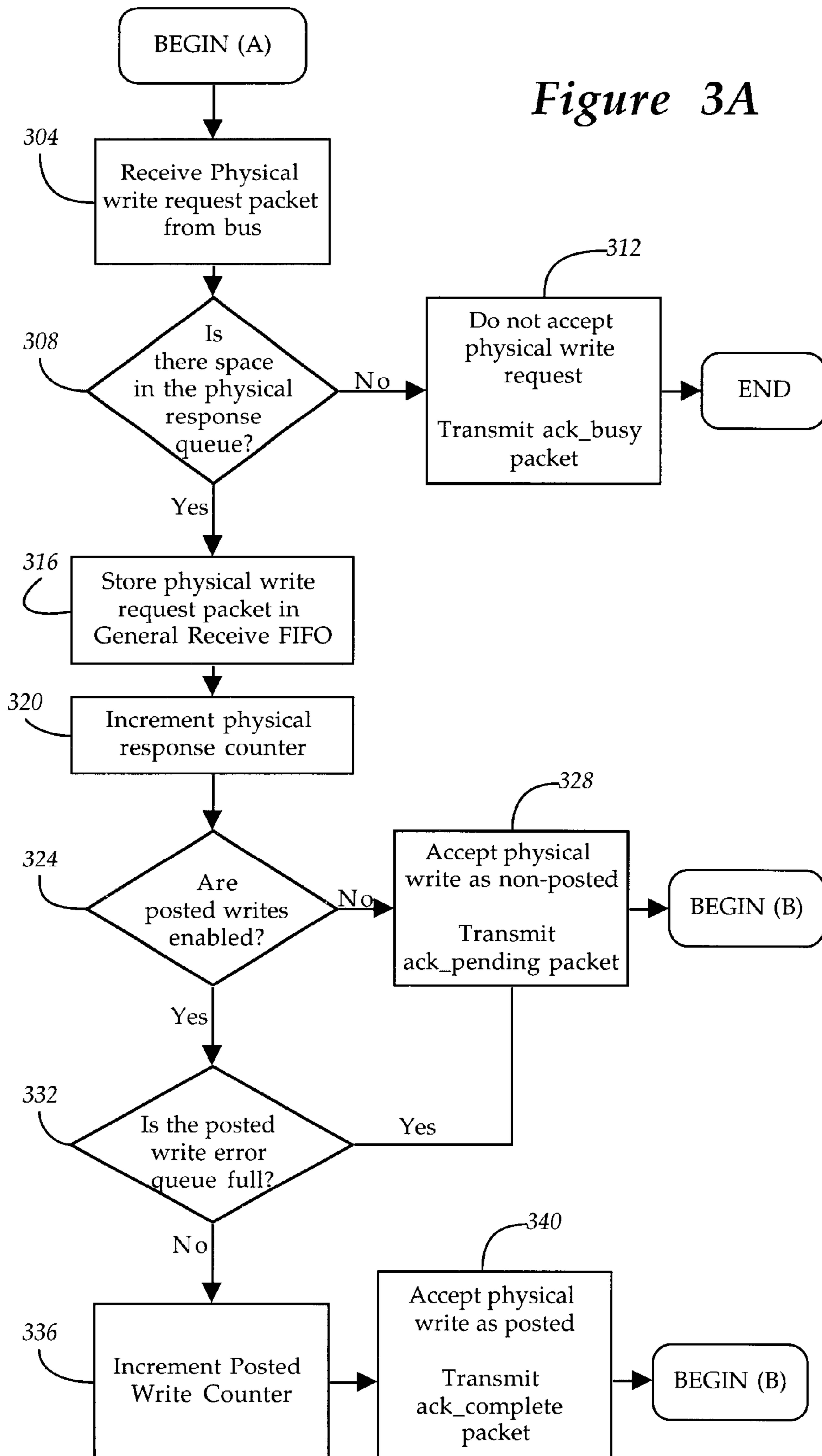
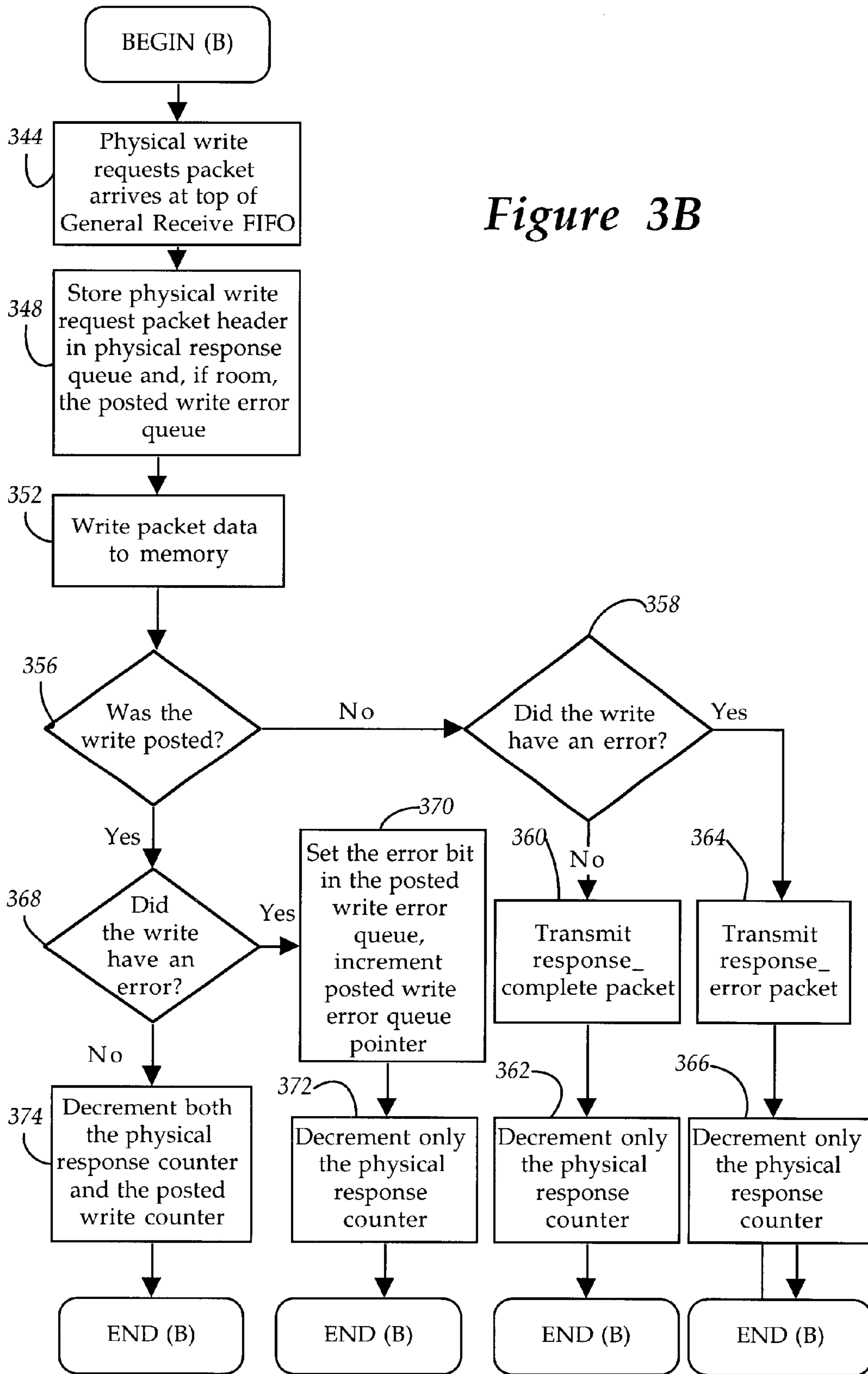


Figure 3B



**PHYSICAL WRITE PACKETS PROCESSING
WHEN POSTED WRITE ERROR QUEUE IS
FULL, WITH POSTED WRITE ERROR
QUEUE STORING PHYSICAL WRITE
REQUESTS WHEN POSTED WRITE PACKET
FAILS**

BACKGROUND OF THE INVENTION

Field of the Invention

The invention applies to the field of interface circuits connecting memory systems to a bus. The invention is particularly applicable to the field of handling pending memory request signals from a bus.

Background Information

A general purpose computer system typically includes a processor, memory, and one or more peripheral devices coupled together by one or more buses. These buses may use asynchronous transmission, isochronous transmission or a combination of the two. Asynchronous transmission places an emphasis on guaranteed delivery of the data. In asynchronous transmission, the recipient of the data, typically a processor acknowledges when asynchronous data has arrived and has been properly written to memory. Isochronous transmission places an emphasis on guaranteed timing of the data. Isochronous data typically has a guaranteed latency in that a packet of data is transferred at predetermined time intervals. In isochronous transmission, when data is lost, the data is often not recoverable. Isochronous transmission is often used in real time communications such as video communication systems.

In order to speed up reading and writing to memory, asynchronous transmission includes a protocol defining a subcategory of data called "physical packets." Typically, a software layer determines how most data packets are handled. However, the software layer is slow. Physical packets bypass the software layer, allowing access to memory via hardware which is faster than the software.

In order to handle physical packets, the device transmitting the data and the device receiving the data must be compatible. Compatible devices usually include hardware and protocols that allow direct reads and writes to specific memory addresses without software intervention. The hardware also generates acknowledge signals to acknowledge receipt of the physical write packet.

Certain specifications, including the IEEE 1394-OHCI (Open Hosts Controller Interface) specify two methods of handling a physical packet, containing a write request. In a first method, when a write request is received, the receiving device outputs an acknowledgment pending ("ACK_PENDING") packet or signal indicating that the write request has been received. When processing of the received write request is complete and the data is written to an appropriate section of memory, a response packet, such as an ACK_COMPLETE packet is transmitted.

The IEEE-1394-OHCI specification also defines a second method of handling write requests as a "posted write." When handling posted writes, the hardware of the receiving device transmits an ACK_COMPLETE packet upon receipt of a write request in a physical packet. The received write request is stored in a buffer in the hardware of the receiving device to be executed at a later time. If, at the later time, the data is properly written to memory, no further action needs to be taken because the ACK_COMPLETE packet which was transmitted indicated that the information was already

properly written to memory. However, if the receiving device is unable to execute the write request, an error occurs. The software of the receiving device handles the error. The software may re-route the write request. Typically, software in the receiving device transmits an error packet to the originator of the write request indicating that the ACK_COMPLETE packet is invalid and that the data has not been properly written to memory. However, until software clears the error, the buffer maintains the information corresponding to the write request, preventing further receiving of write requests. Because software can be slow, an error in a posted write can significantly slow down operation of the system.

Thus, an improved method of handling physical packets containing write requests is needed.

SUMMARY OF THE INVENTION

A circuit for handling memory access request is described. The circuit includes a receive memory device to temporarily store physical packets, including memory access requests from a bus. The physical packets include write requests. A posted write error queue is coupled to the receive memory device. The posted write error queue stores physical write requests for processing when a physical write request that was handled as a posted write request fails. A physical response queue also coupled to the memory device continues to accept non-posted write packets when the posted write error queue is full.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates one embodiment of a physical packet handling circuit.

FIG. 2 is a table summarizing the acknowledgment codes output by the circuit of FIG. 1.

FIGS. 3A and 3B illustrates the operation of the circuit of FIG. 1.

DETAILED DESCRIPTION OF THE
INVENTION

In the following description, a system and method will be described for handling physical packets transmitted from a bus to a physical packet handling circuit. In the description, numerous specific details will be given including circuits, flow diagrams, etc., in order to provide a thorough understanding of the present invention. In other instances, well-known structures and techniques have not been shown in detail because to do so would unnecessarily obscure the present invention. The specific arrangements and methods described here are illustrative of the principles of the present invention. Numerous modifications in form and detail may be made by those of ordinary skill in the art without departing from the scope of the present invention.

One embodiment of a physical packet handling circuit **100** is shown in FIG. 1. The physical packet handling circuit includes memory devices, such as a receive First-In, First-Out memory (FIFO) **104** which receives physical packets from a **1394** bus **106**. A packet decoder **108**, including logic circuitry coupled to receive FIFO **104**, determines whether the data received from bus **108** is a physical packet type. "Physical packet types" may include write requests, read requests, or lock requests. Write requests write data to a specific memory location, read requests read data from a specific memory location and lock requests perform a compare-swap to a specific memory location. If the data is a physical packet type, packet decoder **108** determines the state of a physical response queue **112** and a posted write error queue **116** to determine how to handle the physical packet type.

Both physical response queue **112** and posted write error queue **116** are buffers which store information until the information is ready to be used. For this illustrated embodiment, physical response queue **112** and posted write error queue **116** are FIFO memory devices, although other memory types may be used. Herein, physical response queue **112** includes a first physical response queue slot **120** and a second physical response queue slot **122**. Each queue slot is configured to store either a physical packet or the header of a physical packet. Thus, as illustrated, the physical response queue **112** can receive a physical packet in the first physical response queue slot **120**, while a prior physical packet is processed in a second physical response queue slot **122**.

When packet decoder **108** determines that a read or lock request physical packet has been received and the physical response queue **112** is not full it places the packet in the receive FIFO. The count of physical response counter **126** indicates the number of requests stored in the physical response queue, thus, concurrent with the transfer of data from the receive FIFO **104** to the physical response queue **112**, the packet decoder **108** transmits an increment signal **124** to a physical response counter **126**. Packet decoder **108** also outputs an acknowledgment pending (“ACK_PENDING”) packet on acknowledgment code line **128**.

When packet decoder **108** determines that a received read or lock physical packet cannot be accepted because physical response queue **112** is full and unable to handle additional read or lock requests, packet decoder **108** transmits an acknowledgment busy (“ACK_BUSY”) on code line **128**. In the illustrated embodiment, packet decoder **108** determines whether physical response queue **112** is full by comparing the physical count signal from physical response counter **126** on line **130** to the maximum size of physical response queue **112**. When the count in the physical count signal and the number of slots in the physical response queue are equal, physical response queue **112** is full. In the illustrated embodiment, the maximum number of physical packets that can be stored in the physical response queue is two.

When a physical request packet arrives at the top of the general receive FIFO, the packet header is placed in the physical response queue. When the physical request is a read or lock request, a physical response direct memory access (DMA) **134** executes the request. After the read or lock request is executed, the information stored in physical response queue **112** corresponding to the read or locked data is deleted from the physical response queue and the DMA transmits a decrement signal along decrement line **138** to decrement physical response counter **126**.

When packet decoder **108** determines that a received physical packet is a write request, physical packet handling circuit **100** determines whether posted writes are enabled. When posted writes are not enabled, and physical response queue **112** is not full, the incoming write requests are stored in received FIFO **104** and the packet decoder **108** outputs an ACK_PENDING packet. When the write requests arrives at the top of the receive FIFO, the packet header is stored in the physical response queue. After DMA **134** executes the write request and writes the data to the system memory **136**, the physical response DMA engine transmits a response packet. The DMA removes the data from write request queue **112** and decrements physical response counter **126**.

Some specifications, including the IEEE 1394 OHCI specification allow write requests to be handled as posted writes. When posted writes are allowed, posted write error queue **116** is used in parallel with physical response queue

112. As receive FIFO **104** receives a write request, packet decoder **108** determines whether physical response queue **112** and posted write error queue **116** are full. Packet decoder **108** determines whether posted write error queue **116** is full by comparing a count from a posted write counter **146** with the storage capacity of the posted write error queue. In the embodiment illustrated in FIG. 1, posted write error queue **116** has a first posted write error queue slot **140** and a second posted write error queue slot **142**, for a maximum capacity of two, although alternative embodiments may include only one error queue slot or three or more additional posted write error queue slots to handle larger numbers of posted write errors.

When the posted write error queue is not full, the write request is handled as a posted write and receive FIFO **104** forwards the write request to both physical response queue **112** and posted write error queue **116**. Both queues store the packet header which includes data needed for responding to the posted write, which typically includes a source identification to identify the source of the write request, an address indicating where in memory, the data is to be stored.

When a write request is stored in receive FIFO **104**, packet decoder **108** outputs an ACK_COMPLETE packet on code line **128**. When the packet arrives at the top of the receive FIFO, the packet header is stored in the physical response queue and the posted write error queue. The write requests remain in physical response queue **112** and posted write error queue **116** until physical response DMA **134** writes the data successfully to system memory **136**. When the data is successfully written to system memory **136**, the write request is removed from physical response queue **112** and physical response DMA **134** transmits a decrement signal to physical response counter **126**. The data is also removed from posted write error queue **116** and physical response DMA **134** decrements posted write counter **146** by transmitting a counter decrement signal along decrement line **152** through gate **154**. No further acknowledgment codes regarding the write packet need to be transmitted because the ACK_COMPLETE signal has already been transmitted indicating successful writing to memory.

When physical response DMA **134** attempts to write to system memory **136** and the write is unsuccessful, a posted write error occurs. Posted write errors are undesirable and require that the ACK_COMPLETE signal already output from code line **128** be corrected. Such correction is handled by software. However, software handling of posted write errors takes significant amounts of time. In systems lacking an adequate physical response queue, handling of write requests may be suspended until the posted write error is corrected. However, in the illustrated embodiment, physical response DMA **134** clears the write request which produced the posted write errors from the physical response queue before software has completed handling of the posted write error. The cleared data allows new physical packets to flow into general receive FIFO and into physical response queue **112**. Posted write error queue **116** retains the header data corresponding to the posted write error until software appropriately handles the error. After software has properly handled the write error, the corresponding write request may be removed from the posted write error queue and the software transmits a decrement counter signal along software posted write error queue read line **156** through gate **154**, decrementing posted write counter **126**.

As software handles errors in posted write error queue **116**, physical response queue **112** continues to receive write requests as posted writes until posted write error queue **116** is full. In the illustrated embodiment, this occurs when there

are two errors in posted write error queue **116**. When the posted write error queue is full, the physical response queue may still receive write requests as a non-posted write requests. When the physical response queue receives a non-posted write request, packet decoder **108** transmits an **ACK_PENDING** packet along code line **128**. After executing the non-posted write request, packet decoder **108** transmits a response complete packet. When software clears at least one slot in the posted write error queue, new write requests will be handled as posted writes.

FIG. **2** is a table that summarizes the acknowledgment codes output by packet decoder **108**. The acknowledgment codes output **204** by the packet decoder **108** depends on physical packet type **208**, the state of physical response queue **212**, and the state of posted write error queue **216**. When the physical packet type is a read or lock request and the physical response queue is not full, an **ACK_PENDING** packet is output, as illustrated in row **220**. When the physical response queue is full, the read or lock request cannot be received and an **ACK_BUSY** packet is output, as illustrated in row **224**.

Physical packets containing write requests may be handled as either posted writes or non-posted writes. When both the physical response queue and the posted write error queue are not full, incoming write requests may be treated as a posted write. In a posted write, an **ACK_COMPLETE** packet is output at the time at which the write request is received, as illustrated in row **228**. When only the posted write error queue is full but the physical response has space, the write request will be handled as a non-posted write request and an **ACK_PENDING** packet will be transmitted, as illustrated in row **232**. Later, a response packet is output after the write requests is executed and data is written to memory. When the physical response queue is full, as illustrated in row **236**, an **ACK_BUSY** signal is output because the write request cannot be handled until a slot is available in the physical response queue.

FIG. **3A** illustrates the operations executed by packet decoder **108** when in the embodiment of the invention shown in FIG. **1** handles a physical write request. In block **304**, the physical packet handling circuit receives a physical packet containing a write requests. When in decision block **308**, an indicator circuit indicates that the physical response queue does not have space, the physical packet handling circuit does not accept the physical write request and outputs a signal indicating that the circuit is busy by transmitting an **ACK_BUSY** packet in block **312**. In the embodiment illustrated in FIG. **1**, the indicator circuit is physical response counter **126**. When the indicator circuit indicates that there is space in the physical response queue, the write request is stored in the general receive FIFO, in block **316**. The accepted physical write request is recorded in the indicator circuit (e.g., a counter) in block **320**.

In decision block **324**, the physical packet handling circuit determines whether communicating devices are compatible and whether the protocol used between the two communicating devices handles posted writes. In one embodiment, whether posted writes are handled, is determined by the state of a posted write enable signal. When the enable signal indicates that posted writes are not handled, incoming write requests will be accepted as a non-posted write request. Thus, upon receipt of a write requests, an **ACK_PENDING** signal will be output in block **328** acknowledging receipt of the write request.

When posted writes are enabled in decision block **324**, a posted write indicator circuit corresponding to the posted

write error queue, determines in decision block **332** whether the posted write error queue can handle the posted write. In the embodiment shown in FIG. **1**, the posted write indicator circuit corresponds to posted write counter **146**. When the posted write indicator circuit indicates that the posted write error queue is full, the physical packet handling circuit handles the write request as a non-posted write request following the procedures outlined in block **328**. When the posted write indicator circuit indicates that the posted write error queue has open spaces or slots, the incoming write request is stored in the posted write error queue in block **348**, and the posted write queue indicator circuit is updated. In the embodiment illustrated in FIG. **1**, the indicator circuits are updated by respectively incrementing posted write counter **146** as described in block **336**. In block **340**, the packet decoder accepts the physical write as a posted write and outputs an **ACK_COMPLETE** packet.

FIG. **3B** illustrates the operation executed by the physical DMA when the packet decoder **108** of the invention shown in FIG. **1** accepts a physical write request. In block **344** the physical write request packet eventually arrives at the top of the general receive FIFO in block **344**. In block **348** the header corresponding to the physical write request packet, or a physical write request packet header is stored in the physical response queue in block **348**. If the posted write error queue is not full, the header is also stored in the posted write error queue. In block **352** the physical DMA attempts to execute the physical write request packet by writing packet data to a system memory.

In decision **356**, the physical DMA determines whether the write request packet was handled as a posted or non-posted write. If in decision block **356**, the write request packet was handled as a non-posted write request, the physical DMA then determines in block **358** whether the write request performed in block **352** resulted in an error. When the write request performed in block **352** does not result in an error and the write request was handled as a non-posted write request, the physical DMA outputs a **RESPONSE_COMPLETE** packet in block **360** and decrements the physical response counter in block **362**.

When in decision block **358**, it is determined that the non-posted write request resulted in an error, the physical DMA transmits a **RESPONSE_ERROR** packet in block **364**. The **RESPONSE_ERROR** packet indicates that the attempt to write the non-posted write to memory was unsuccessful. In block **366**, the physical DMA decrements the physical response counter.

When in decision block **356**, it is determined that the physical request processed in block **352** was a posted write, the physical DMA determines in block **368** whether the posted write was successfully written to memory or whether the posted write resulted in an error. When in decision block **368**, it is determined that the posted write resulted in an error, an error bit is set in the posted write error queue and a pointer indicating the location of the data which the physical DMA was unable to write to memory is incremented in block **370**. The system also decrements the physical response counter in block **372**.

When it is determined in decision block **368** that the posted write does not produce an error, and thus, the posted write was successfully written to memory in block **352**, the physical DMA decrements both the physical response counter and the posted write counter in block **374**.

Although this invention has been shown in relation to a particular embodiment, it should not be considered to be so limited. Rather, the invention is limited only by the scope of the appended claims.

What is claimed is:

1. A circuit for handling memory access requests comprising:

a receive memory device to temporarily store physical packets of memory access requests from a bus, the physical packets including physical write request packets;

a posted write error queue coupled to the receive memory device, the posted write error queue to store physical write requests for processing when a physical write request packet that was handled as a posted write request fails; and

a physical response queue coupled to the receive memory device, the physical response queue accepts physical write packets even when the posted write error queue is full.

2. The circuit of claim **1** wherein an acknowledgment packet is transmitted when the physical response queue accepts a physical write packet.

3. The circuit of claim **1** wherein the posted write error queue is capable of storing at least two posted write errors.

4. The circuit of claim **1** wherein the physical response queue is capable of storing at least two physical write request packets.

5. The circuit of claim **1** wherein an acknowledgment circuit outputs a busy packet upon receipt of a memory access request while the physical response queue is full.

6. The circuit of claim **1** further comprising a posted write counter which is incremented when a physical write request is received and the posted write counter is not at a maximum value.

7. The circuit of claim **6** wherein the posted write counter is decremented when a posted write is successfully written to a destination memory.

8. The circuit of claim **1** further comprising a physical response counter which is incremented when a physical write request packet arrives.

9. The circuit of claim **8** wherein the physical response counter is decremented when an attempt to write a posted write to destination memory is made, regardless of whether the attempt to write to destination memory is successful.

10. The circuit of claim **1** wherein the posted write error queue is capable of storing only one posted write error.

11. The circuit of claim **1** wherein the physical response queue is capable of storing only one physical write request packet.

12. A method of accepting physical write requests comprising:

determining when a posted write error queue is full;

processing a physical write request as a posted write when the posted write error queue is not full, and,

processing a physical write request as a non-posted write request when the posted write error queue is full.

13. The method of claim **12** further comprising the steps of:

outputting an ACK_COMPLETE packet upon receipt of a physical write request when the posted write error queue is not full; and

outputting an ACK_PENDING packet upon receipt of a physical write request when the posted write error queue is full.

14. The method of claim **12** further comprising the steps of:

transferring the physical write request to a physical response queue; and

transferring a copy of the physical write request to a posted write error queue when the posted write error queue is not full.

15. The method of claim **14** further comprising the steps of:

attempting to execute the physical write request by writing data to system memory;

deleting the physical write request from the physical response queue after attempting to execute the physical write request; and,

processing via software errors which may occur in the attempt to write using the copy of the physical write request stored in the posted write error queue.

16. The method of claim **12** further comprising the step of updating a counter corresponding to a physical response queue when a physical write request is received.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,366,968 B1
DATED : April 2, 2002
INVENTOR(S) : Hunsaker

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 2,
Line 34, delete "illustrates", insert -- illustrate --.

Signed and Sealed this

Twenty-fifth Day of February, 2003

A handwritten signature in black ink, appearing to read "James E. Rogan", with a horizontal line drawn underneath it.

JAMES E. ROGAN
Director of the United States Patent and Trademark Office